MISB MOTION IMAGERY STANDARDS BOARD	MISB ST 1507
STANDARD	
Motion Imagery Sensor Timing Metadata	**25 February 2016**

1 Scope

Sensors producing Motion Imagery have various types of timing characteristics. Two common sensors are global shutter, in which a complete image is formed at one time, and rolling shutter, in which portions (typically each "line") of an image are formed sequentially in time. Capturing the timing characteristics as metadata provides the end user an ability to compensate for the effects of a sensor type, and derive more information about the scene structure and kinematics.

This standard defines the method for formatting the timing information in KLV, and provides the KLV metadata specification as a Sensor Timing Local Set for sensor timing.

2 References

[1] MISB MISP-2016.2: Motion Imagery Handbook, Feb 2016.

[2] MISB ST 0603.4 MISP Time System and Timestamps, Feb 2016.

[3] MISB ST 0807.16 MISB KLV Metadata Dictionary, Feb 2016.

[4] MISB RP 0701 Common Metadata System: Structure, Aug 2007.

3 Terms, Acronyms and Definitions

Global Shutter	A sensor imaging mechanism whereby all samples of the entire image are captured at the same instant
Rolling Shutter	A sensor imaging mechanism whereby samples of an image are captured at different instants of time by stepping across the Detector Group [1] line by line
Tuple (n-Tuple)	A sequence (an ordered list) of zero of more elements
UL	Universal Label

Definitions for the terminology (words capitalized) in this document can be found in the Motion Imagery Handbook [1], which also provides greater depth of the basic principles discussed here.

4 Revision History

Revision	Date	Summary of Changes
ST 1507	02/25/2016	Initial release

5 Introduction

Although this standard contains all of the necessary information for implementation, it is highly recommended to review the pertinent sections of the Motion Imagery Handbook before beginning development.

Sensor timing metadata defined in this standard, and the Motion Imagery Handbook [1], is designed to be flexible and applicable to many different types of sensor timing. Sensor timing is categorized into four types: global shutter, type 1 rolling shutter, type 2 rolling shutter and multi-Region shutter.

- With a global shutter all Detectors in a sensor are exposed with the same exposure time. In a global shutter sensor, a complete image is "frozen" in time (provided the exposure time is short enough such that there is no change in the scene during the Exposure Time). The advantage of a global shutter sensor is superior motion capture capability.
- A Type 1 rolling shutter sensor induces delay between the exposure of each “line” of Detectors resulting in distortions of fast-moving objects or flashes of light.
- A Type 2 rolling shutter sensor induces a small delay between the exposures of each Detector within a “line” and also between each “line”. This sensor timing also results in distortions of fast moving objects or flashes of light.
- A multi-Region shutter sensor exposes different areas of the sensor at different times and in different directions. Multi-Region shutter sensors will likewise produce distortions of fast-moving objects or flashes of light. The Motion Imagery Handbook discusses these in detail.

Rolling shutter or multi-Region shutter distortions behave in a predictable manner; however, with knowledge of a sensor’s motion and its exposure timing, these artifacts can be compensated for or “undone”. Viewed as a benefit, the artifacts can be exploited to ascertain information about the scene structure and kinematics.

The techniques and metadata described in this standard, and amplified in the Motion Imagery Handbook, allow one method to describe the sensor timing for all four shutter types.

A sensor is formed from a number of Detectors called a Detector Group. A Detector Group is comprised of one or more Regions with each Region composed of one or more Sub-Regions, where a Sub-Region is a linear set of temporally-related Detectors (see Figure 1). Each Region is defined by an orientation, which is the direction across the Region two-or-more Sub-Regions are exposed. Regions within a Detector Group can have different orientations. For example, Figure 1 illustrates a Detector Group, where Region A has a top-down orientation and Region B has a right-to-left orientation.

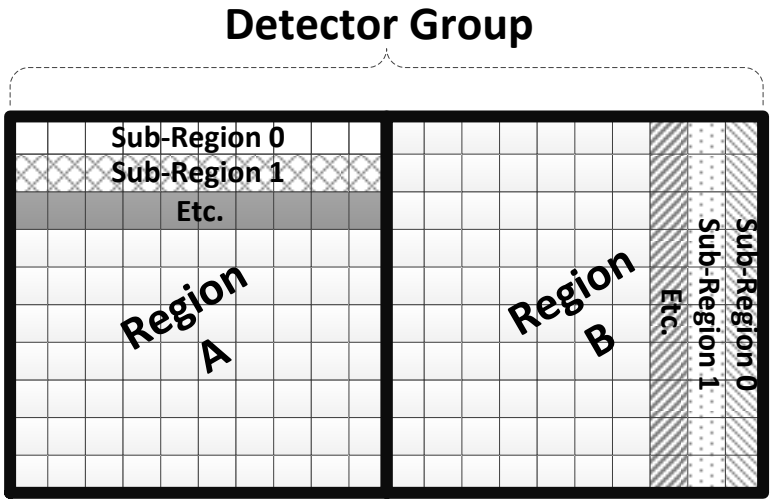

Figure 1: Illustration of a 10 row by 20 column Detector Group divided into two Regions, A and B. Each Region contains 10 Sub-Regions with Region A oriented from top-to-bottom and Region B being oriented from right-to-left.

Each Sub-Region within a Region has a similar Exposure Start Time and equal Exposure Duration for a Detector. An Exposure Configuration for a Detector Group defines the Exposure Time for every Detector in the Detector Group. An Exposure Pattern is a method for representing the Exposure Configuration efficiently by leveraging the temporal patterns within Regions and Sub-Regions; the Motion Imagery Handbook provides details of Exposure Pattern development.

5.1 Exposure Pattern

An Exposure Pattern is determined using information from two, three or four Detectors depending on the relative timing of each Detector. Exposure Patterns are defined using the Exposure Start Time and Exposure End Time of these Detectors within Sub-Regions. An Exposure Pattern is represented as a "tuple" or ordered set of values. The notation used to specify Exposure Start Time and Exposure End Time of a specific Detector is $S_{R,j,i}$ and $E_{R,j,i}$ respectively for the R^{th} Region, j^{th} Sub-Region and i^{th} Detector within the Sub-Region.

Four tuples are defined for specifying the timing of a sensor:

Tuple 0: Indicates the first Detector of a Region along with its Exposure Time. The first Detector defines one of the corner locations of the Region, and also the location of the first Sub-Region. *This tuple is required for all Regions*. The information required for this tuple is: Detector row, Detector column, Exposure Start Time ($S_{R,0,0}$), and Exposure End Time ($E_{R,0,0}$).

Tuple 1: Defines the *intra*-Sub-Region timing pattern. This tuple specifies the location of the last Detector of the first Sub-Region along with its Exposure Start Time. This tuple is used to determine the difference (Δ) in the Exposure Start Time for each Detector within a Sub-Region. *This tuple is optional*; when this tuple is not preset in the metadata set, it is assumed $\Delta = 0$. Note that a Δ computed for the first Sub-Region is assumed the same for all remaining Sub-Regions. The information required for this tuple is: Detector row,

Detector column, and Exposure Start Time ($S_{R,0,M}$), where M is the last detectors in the Sub-Region.

Tuple 2: Defines the *inter*-Sub-Region timing pattern. This tuple specifies the location of the Detector in the second Sub-Region along with its Exposure Start Time. This tuple is used to determine the Sub-Region Delay (γ) within a Region. The Sub-Region delay is assumed as an offset for all Sub-Regions. *This tuple is optional*; if the tuple is not present, then it is assumed $\gamma = 0$. Note that the γ computed between the first two Sub-Regions is assumed the same for all remaining Sub-Regions. The information required for this tuple is: Detector row, Detector column, and Exposure Start Time ($S_{R,1,0}$).

Tuple 3: Identifies the end corner of a Region. This tuple specifies the location of the last Detector of the last Sub-Region, which along with the first tuple defines the size of the Region. *This tuple is required for all Regions*.

Table 1 summarizes these four tuples. The values $D_{R,k}$ are specific locations within a Region, R, for defining bounds and/or timing information.

Table 1: Region R Exposure Pattern Tuples

Tuple	Sub-Region (j)	Detector (i)	Values
Tuple 0 ($D_{R,0}$, $S_{R,0,0}$, $E_{R,0,0}$)	0	0	The location ($D_{R,0}$) of the first detector of the first Sub-Region (0) of Region (R), its Exposure Start Time ($S_{R,0,0}$), and its Exposure End Time ($E_{R,0,0}$). (Row, Col, Exposure Start Time, Exposure End Time)
Tuple 1 ($D_{R,1}$, $S_{R,0,M}$)	0	M	The location ($D_{R,1}$) of the last detector of the first Sub-Region (0) of Region (R), and its Exposure Start Time ($S_{R,0,M}$). (Row, Col, Exposure Start Time)
Tuple 2 ($D_{R,2}$, $S_{R,1,0}$)	1	0	The location ($D_{R,2}$) of the first detector of the second Sub-Region (1) of Region (R), and its Exposure Start Time ($S_{R,1,0}$). (Row, Col, Exposure Start Time)
Tuple 3 ($D_{R,3}$)	N	M	The location ($D_{R,3}$) of the last detector of the last Sub-Region (N) of Region (R). (Row, Col)

Figure 2 illustrates the locations of the values for the example from Figure 1. Each $D_{R,i}$ is a detector location relative to the whole Detector Group, in coordinates of rows and columns, zero based.

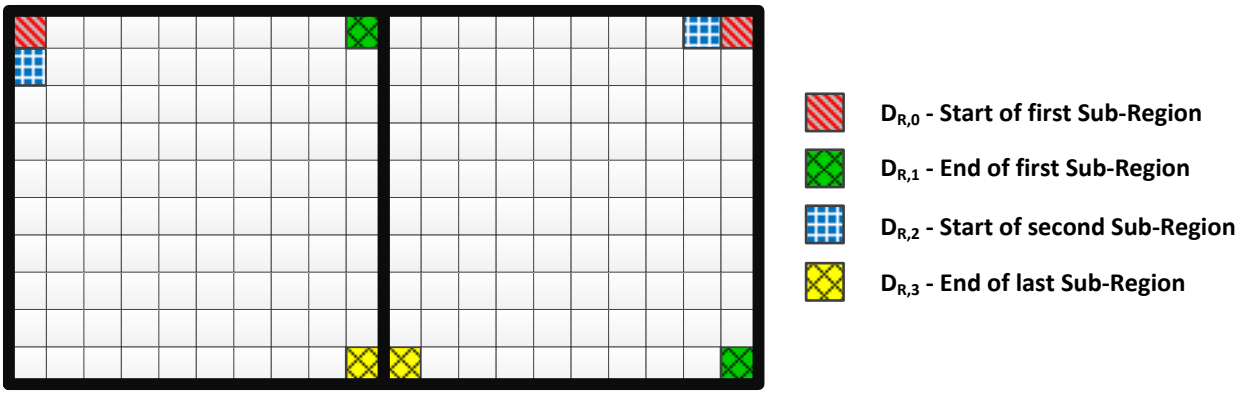

Figure 2: Illustration of the Regions of Figure 1 with the Exposure Pattern Tuples.

5.2 Exposure Time Reference

To reduce the quantity of information needed, all Exposure Start Times and Exposure End Times in the Sensor Timing Local Set are specified as offsets to a reference time, which is the Precision Time Stamp (see MISB ST 0603 [2] for information on the Precision Time Stamp). To guarantee a positive offset, the reference time is chosen *before or equal to* the time of the first exposed Detector in the Detector Group. Offset time values are computed in nanoseconds from the reference time, which is measured in microseconds.

The Exposure Start Time, in concert with the reference time, specifies the instant at which exposure begins for the given Detector. Likewise, the Exposure End Time, in concert with the reference time specifies the instant at which exposure terminates for the given Detector. Note that these time values do not account for Readout times or other systematic delays.

5.3 Windowing

An image sampled from a sensor's Detector Group can be geometrically smaller than the Detector Group for various reasons, such as dimensional requirements and stabilization processes. Although Detector Groups can be constructed to any density, standards specify dimensional requirements for practically reasons. For example, a Detector Group might contain 2048x2048 Detectors, but the application may require a 1920×1080 image; in this case, a match of Detectors to image – or window of Detectors – is needed. Window information thus helps to define the two bounding corner Detectors used in a windowed process. In a stabilization system, the window can change position on the Detector Group from image to image in an attempt to reduce the effects of movement (see the Motion Imagery Handbook for further discussion).

Additionally, the Detector Group and the Image will have different coordinate systems and orientation. The sensor can have any orientation relative to the scene, for example, the light from the scene may be projected onto the Detector Group upside down, or as a mirror image. Producing the Image so that it is right side up requires the window corners to have any orientation.

The necessary window information consists of two Detector corner coordinates C_1 and C_2, with each coordinate specifying a row and column from the Detector Group as listed in Table 2 and illustrated in Figure 3. The corners can define any area within the Detector Group and can have

any orientation. The resulting Image is mapped from the Detector window with C_1 being the upper right corner of the image and C_2 being the lower left corner of the image.

Table 2: Window Corner Values

Corner	Values	Description
C_1	row, column	First corner of the Detector window. This corner becomes the upper left corner of the image.
C_2	row, column	Second corner of the Detector window, which is diagonally opposite from the first. This corner becomes the lower right corner of the image.

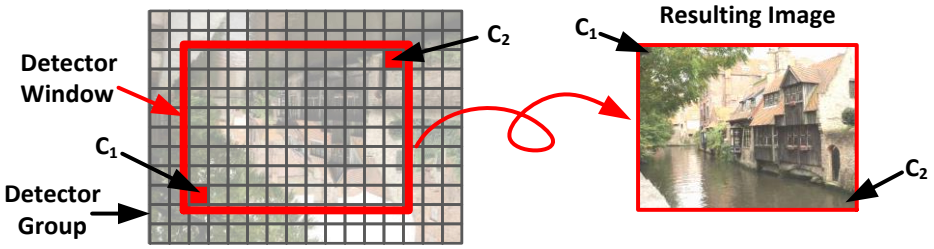

Figure 3: A Detector window within a Detector Group (defined by C1 and C_2) and the resulting Image, which is a rotation and flip (mirror image) of the projected light onto the Detector Group.

The sensor timing information together with the window information are both needed to determine the timing of every sample in the image; however, window information can be transmitted by itself if the Exposure Configuration remains constant.

6 Sensor Timing Local Set

The reference time in combination with Exposure Pattern tuples provides the metadata adequate to specify the Exposure Configuration for a Detector Group. A reference time, specified as a Precision Time Stamp, needs to be supplied within the Motion Imagery Sensor Timing Local Set.

When the Exposure Pattern is invariant from image-to-image it is not needed to be specified per image. However, to ensure that the Exposure Pattern is available throughout a Motion Imagery stream, it needs to be provided periodically, nominally at least once every thirty seconds. The following requirements apply:

Requirement(s)	
ST 1507-01	The Sensor Timing Local Set shall contain a reference time (tag 1) in accordance with MISB ST 0603 [2].
ST 1507-02	Where an Imager uses Exposure Patterns, a Sensor Timing Local Set with Region List (tag 3) defined shall be nominally sent at least once every 30 seconds.

ST 1507-03	Where an Imager uses Exposure Patterns, a Sensor Timing Local Set with Region List (tag 3) defined shall be nominally sent every time the Exposure Pattern information changes.

When an image is sampled as a window on the Detector Group, the corner coordinates (C_1 and C_2) need to be specified. If the window does not change from image-to-image, the window values need not be specified for every image. However, to ensure that the window information is available throughout the Motion Imagery stream, the window information needs to be provided periodically, nominally at least once every thirty seconds. The following requirement applies:

Requirement(s)	
ST 1507-04	Where an Imager utilizes Detector windowing, a Sensor Timing Local Set with Windows Corner Pack (tag 2) shall nominally be sent at least once every 30 seconds.
ST 1507-05	Where an Imager utilizes Detector windowing, a Sensor Timing Local Set with Windows Corner Pack (tag 2) shall nominally be sent every time the Detector window information changes.

The Sensor Timing Local Set's Region List and Windows Corner Pack can be specified independently or together. If the Region List is "constant", but the Window Corner Pack changes per Image only, the Window Corner Pack information in the Sensor Timing Local Set needs to be transmitted per frame. Likewise, if the Window Corner Pack is "constant", but the Region List is changing frequently, only the Region List in the Sensor Timing Local Set needs to be transmitted per frame. Using these techniques will reduce the quantity of metadata.

6.1 KLV Specification

The Sensor Timing Local Set, as summarized in Table 3, defines Key-Length-Value (KLV) elements needed to specify sensor timing information. The Tag column defines the KLV tag when encoding the KLV element. The Key Value column defines the universal label (UL) for the element as defined in the KLV dictionary [3]. The Element Name is an informational name for the data element. The Data Type is the representation of the elements value. The Length is the number of bytes used by the elements value; lengths denoted as "V" are variable and are computed at runtime. Notes provide additional detail about the value.

Table 3: Sensor Timing Local Set

Sensor Timing Local Set 06.0E.2B.34.02.0B.01.01 0E.01.03.02.01.00.00.00 (CRC 13079)					
Tag	**Key Value (hex)**	**Element Name**	**Data Type**	**Length (Bytes)**	**Notes**
1	06.0E.2B.34.01.01.01.03 07.02.01.01.01.05.00.00 (CRC 64827)	Reference Time (Precision Time Stamp)	Unsigned Integer	8	Precision Time Stamp to be used as the reference for all offsets within the Sensor Timing Local Set. Units in microseconds. See Section 5.2.
2	06.0E.2B.34.02.05.01.01 0E.01.03.02.01.01.00.00 (CRC 22365)	Window Corners Pack	Pack	V	Window corners C_1 and C_2 - see Section 5.3.
3	06.0E.2B.34.02.0B.01.01 0E.01.03.02.01.02.00.00 (CRC 23927)	Region List	Local Set	V	Local Set of Region Descriptions, each tag specifies timing parameters for a Region of an image. See Table 5.
4	06.0E.2B.34.01.01.01.01 0E.01 02.03.5E.00.00.00 (CRC 31377)	CRC-16-CCITT	Unsigned Integer	2	CRC of the Sensor Timing Local Set, calculated per MISB RP 0701 [4].

6.1.1 Reference Time

The reference time is specified as a Precision Time Stamp in the Sensor Timing Local Set (see MISB ST 0603 for information on the Precision Time Stamp). To maintain a positive offset, the reference time is chosen *before or equal to* the time of the first exposed detector in the Detector Group. Offset time values are computed in nanoseconds from the reference time, which is measured in microseconds.

Requirement	
ST 1507-06	The reference time value shall be before or equal to the first Exposure Start Time of a Detector Group.

6.1.2 Window Corners Pack

Table 4 defines the Window Corners Pack, which is used to encode the corner information of a window as described in Section 5.3. The Key Value indicates the KLV Dictionary key for the value. The Element Name is the identifier from Section 5.3 associated with the value. The Data Type specifies the bit representation of the value; values start at zero. The Length is the number of bytes used for the value. Since all values in the Windows Corner Pack are BER, the length is variable and is determined when the pack is constructed or parsed. The Units specify the units of

the value. In the Windows Corner Pack, the units are coordinates in the Detector Group, so each value is measured as a number of Detectors. The Notes provide additional information about the value. All four values of rows or columns in the Windows Corner Pack are zero based, i.e. each value starts at zero. When the Window Corners Pack is not included in the Sensor Timing Local Set, the full size of the Detector Group is assumed.

Table 4: Window Corners Pack

Window Corners Pack 06.0E.2B.34.02.05.01.01 0E.01.03.02.01.01.00.00 (CRC 22365)					
Key Value (hex)	**Element Name**	**Data Type**	**Length (Bytes)**	**Units**	**Notes**
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.01.00.00 (CRC 44071)	C_1 Row	BER-OID	V	Detectors	Detector row for the first corner of the Detector window. First detector row starts at zero.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.02.00.00 (CRC 62839)	C_1 Column	BER-OID	V	Detectors	Detector column for the first corner of the Detector window. First detector column starts at zero.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.01.00.00 (CRC 44071)	C_2 Row	BER-OID	V	Detectors	Detector row for the second corner of the Detector window. First detector row starts at zero.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.02.00.00 (CRC 62839)	C_2 Column	BER-OID	V	Detectors	Detector column for the second corner of the Detector window. First detector column starts at zero.

6.1.3 Region List

The Sensor Timing Local Set will contain a Region List, which is a Region Local Set containing metadata describing a Region within a Detector Group. Each tag in the Region Local Set defines one of four "styles" of timing that can be used. Typically, all Regions within a Detector Group will have the same style of timing, in which case, the Region Local Set will have multiples of the same tag number used, but with the value portion defining a different Region. For example, if a Detector Group has four Regions all specifying a Tag 3, the Region Local Set will have four Tag 3 entries.

Table 5 defines the Region Local Set. The data type for all values is tuples, which is defined in Table 6. The Tag column denotes the KLV tag when encoding a value in the Region Local Set. The "Tuple 0" through "Tuple 3" column indicates whether the specified tuple is included in the

value portion of the metadata element. Each tuple is a KLV Pack value (i.e. no key or length value is used as defined in Table 6. Tuples are ordered in the value portion according to their number, i.e. Tuple 0 first, Tuple 1 second, etc. The Notes column provides additional information about the given Region Style.

Table 5: Region Local Set

Region Local Set 06.0E.2B.34.02.0B.01.01 0E.01.03.02.01.02.00.00 (CRC 23927)					
Tag	**Tuple 0**	**Tuple 1**	**Tuple 2**	**Tuple 3**	**Notes**
1	Yes	No	No	Yes	Region is Global Shutter
2	Yes	Yes	No	Yes	Sub-Region Detectors have unique Exposure Start Times
3	Yes	No	Yes	Yes	Each Sub-Region has delay after exposure
4	Yes	Yes	Yes	Yes	Each Sub-Region Detectors have unique Exposure Times and each Sub-Region has delay after exposure

There are four tuple types, which are defined in Table 6. The data type for each tuple is defined in Table 7. The Name column defines the name for the specific tuple. The Description column describes what the tuple represents. Exposure Start Time offset and Exposure End Time offset are the time offsets referenced to the reference time discussed in Section 6.1.1.

Table 6: Tuple Descriptions

Name	Description
Tuple 0	Tuple specifying the row, column, Exposure Start Time offset, and Exposure End Time offset for the first detector ($D_{R,0}$) of the first Sub-Region of a Region.
Tuple 1	Tuple specifying the row, column, and Exposure Start Time offset for the last detector ($D_{R,1}$) of the first Sub-Region of a Region.
Tuple 2	Tuple specifying the row, column, and Exposure Start Time offset for the first detector ($D_{R,2}$) of the second Sub-Region of a Region.
Tuple 3	Tuple specifying the row and column of the last Detector ($D_{R,3}$) of the last Sub-Region of the Region.

Requirement(s)	
ST 1507-07	Where a Region List (Tag 3) in the Sensor Timing Local Set is specified, the Region List shall contain Region definitions for the entire Detector Group.
ST 1507-08	A Windows Corner Pack (Tag 2), a Region List (Tag 3), or both shall be present in the Sensor Timing Local Set.

6.1.3.1 Region Tuple Element

Table 7 defines the components of a Region Tuple Pack. Each Region Tuple Element consists of at least a row and column component, but can additionally include start offset, and end offset

value. The Key Value indicates the KLV Dictionary key for the value. The Element Name is the identifier (from Section 5.1) for the value. The Data Type specifies the bit representation of the value; values start at zero. The Length is the number of bytes used for the value. Since all values in the Region Tuple Pack are BER, the length is variable, and is determined when the pack is constructed and parsed. The Units specify the units of the value. In the Region Tuple Pack the first two value's units are coordinates in the Detector Group, so these values are measured as a number of Detectors. The Notes provide additional information about the value. All four values in the Region Tuple Pack are zero based, i.e. each value starts at zero. When used in the Region Local Set only the Value portion of this Pack is used; the Key and Length are not used.

Table 7: Region Tuple Pack

Region Tuple Pack 06.0E.2B.34.02.05.01.01.0E.01.03.02.01.03.00.00 (CRC 14653)					
Key Value (hex)	**Element Name**	**Data Type**	**Length (Bytes)**	**Units**	**Notes**
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.01.00.00 (CRC 44071)	Row	BER-OID	V	Detectors	The Detector row. First detector row starts at zero.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.02.00.00 (CRC 62839)	Col	BER-OID	V	Detectors	The Detector column. First detector column starts at zero.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.03.00.00 (CRC 49735)	Exposure Start Time offset	BER-OID	V	Nano-seconds	The time offset from the reference time representing the Exposure Start Time.
06.0E.2B.34.01.01.01.01 0E.01.01.03.3F.04.00.00 (CRC 18391)	Exposure End Time offset	BER-OID	V	Nano-seconds	The time offset from the reference time representing the Exposure End Time.

6.1.4 CRC-16-CCITT

CRC of the Sensor Timing Local Set, calculated per MISB RP 0701 [4].

Requirement(s)	
ST 1507-09	The Sensor Timing Local Set shall contain a CRC-16-CCITT (Tag 5).
ST 1507-10	The CRC-16-CCITT (Tag 5) shall be calculated in accordance with MISB RP 0701 [4].
ST 1507-11	The CRC-16-CCITT (Tag 5) shall be the last element in the Sensor Timing Local Set.